Basics of Mechanical Engineering-1

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Week 09

Lecture 39

Testing for hardness, and fracture

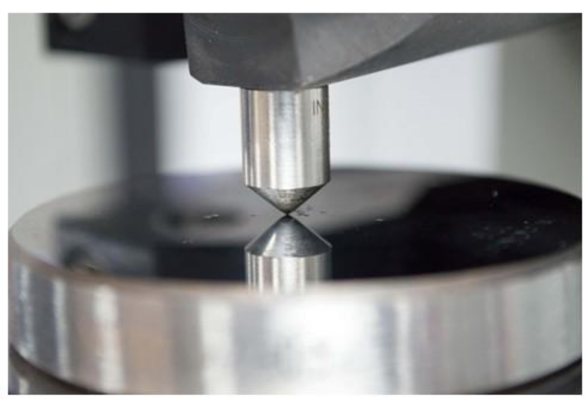
Welcome to the last lecture of this week, where we're discussing the material testing. We've discussed about Tensile Test, Compression Test, Bending Test, and Impact Test in the last lectures. I will focus on testing for Hardness in this lecture, and I will also talk about testing for Fracture.

In the course, Basics of Mechanical Engineering-1, we are discussing the solid mechanics, we are discussing the theory of machines, we are linkage mechanisms and other things have also been discussed by Professor Ramkumar. So, this would be the last part that we will be discussing the solid mechanics, we were discussing the testing. Further, I will take you to the theory of machines part in the coming lectures in the next week.

Hardness Testing

- Hardness is the resistance of a body to the indentation by another (harder) body.
- In other words hardness is the mechanical resistance of a material (specimen) to mechanical indentation by another harder body (indenter).
- The hardest natural material is the diamond, which is used for the indenter (industrial diamond).

Hardness | Strength
Resistance to indentation | Resistance to deformation



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Now, when we talk about Hardness, what is Hardness Testing? First, let us see what is hardness. Hardness is the resistance of a body to indentation by another harder body. Only harder body can indent into a softer body.

For instance, you use knife to cut cheese. Cheese is softer, knife is harder. You use saw made of mild steel or saw blades to cut the wood. Wood is softer and you use the saw blades made up of high speed steel to cut mild steel. High speed steel is harder.

So, it is always the harder material that indents into the softer material. In other words, hardness is the mechanical resistance of a material specimen to mechanical indentation by another harder body that is indenter. So, specimen is one term, indenter is another term, indenter is harder body, specimen is a softer body. The hardest natural material is diamond which is used for indenter that is for industrial applications as well industrial diamond is there which is used for indentation and diamond is not very commonly used for indentation. I will show you the indenter materials in this lecture and also we will see where diamond is used generally.

So, hardness and strength are two different entities. Hardness, strength. Hardness definition differs from definition of strength, which is resistance of material to deformation and separation.

Hardness Testing Objective

Hardness testing is one of the most widely used methods in mechanical materials testing, especially for metals.

- This test method can be used to find qualitative relations to other material properties (e.g., strength, stiffness, density) or to the material behavior under certain stresses (e.g., abrasion resistance).
- Hardness testing is a comparatively easy and fast method to perform; it causes relatively little destruction, that is, only minor superficial damage remains on the specimen surface.
- It also provides a quality control option (incoming and outgoing goods inspection).

– A wide range of specimen geometries are used. (can be)

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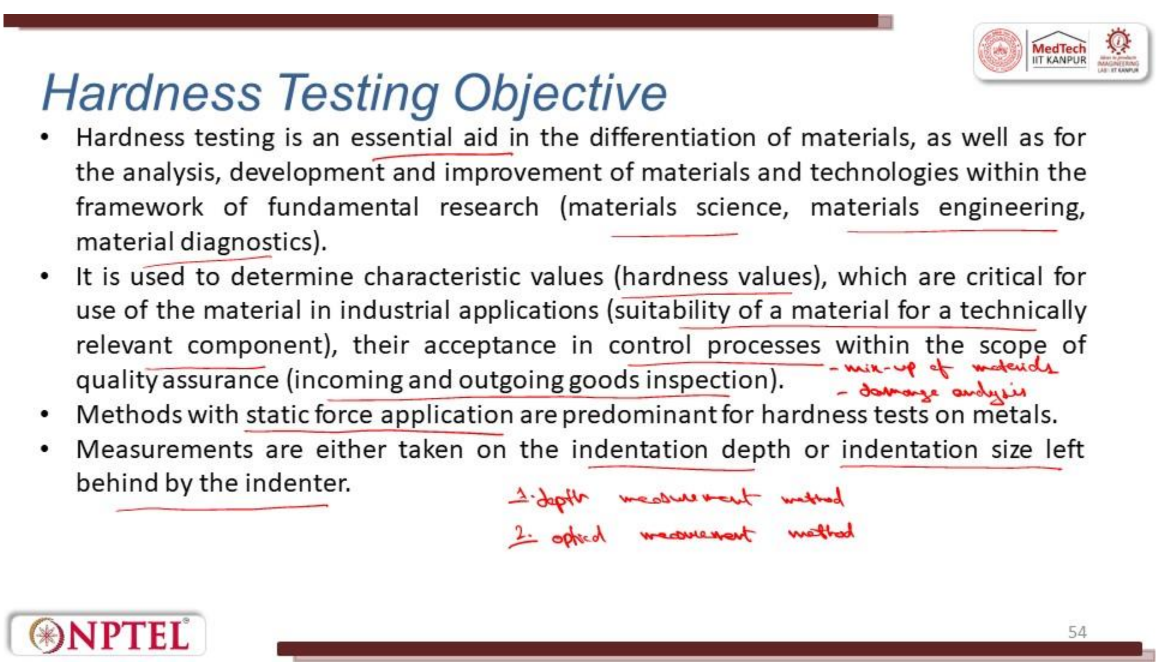
This is resistance to deformation and hardness is resistance to indentation hardness testing is one of the most widely used methods in mechanical material testing especially for metals This method can be used to find qualitative relations to other material properties, for example, strength, stiffness, density, or to the material behavior under certain stresses, for example, abrasion resistance even.

Hardness testing is a comparatively easy and fast method to perform. It causes relatively little destruction because it is only indentation. We are not doing any destructive testing. It is only indentation and the specimen can be used time and again to check for the indentation for the hardness at the different intervals whenever the requirements are there. Only minor superficial damage remains on the specimen's surface because it is only indentation that is also of the order of a few millimeters.

It provides a quality control option that is incoming and outgoing goods inspection like hardness is used for the incoming and outgoing goods inspection whether the material is having adequate hardness to be used as a raw material or whether as a finished good is it hard enough to go to the use in realistic environments. So, incoming and outgoing inspection hardness is used because this is not a destructive testing. We do not break the material. Here, a wide range of specimen geometries can also be tested using hardness testing method. Wide range of specimen geometries are used or can be used.

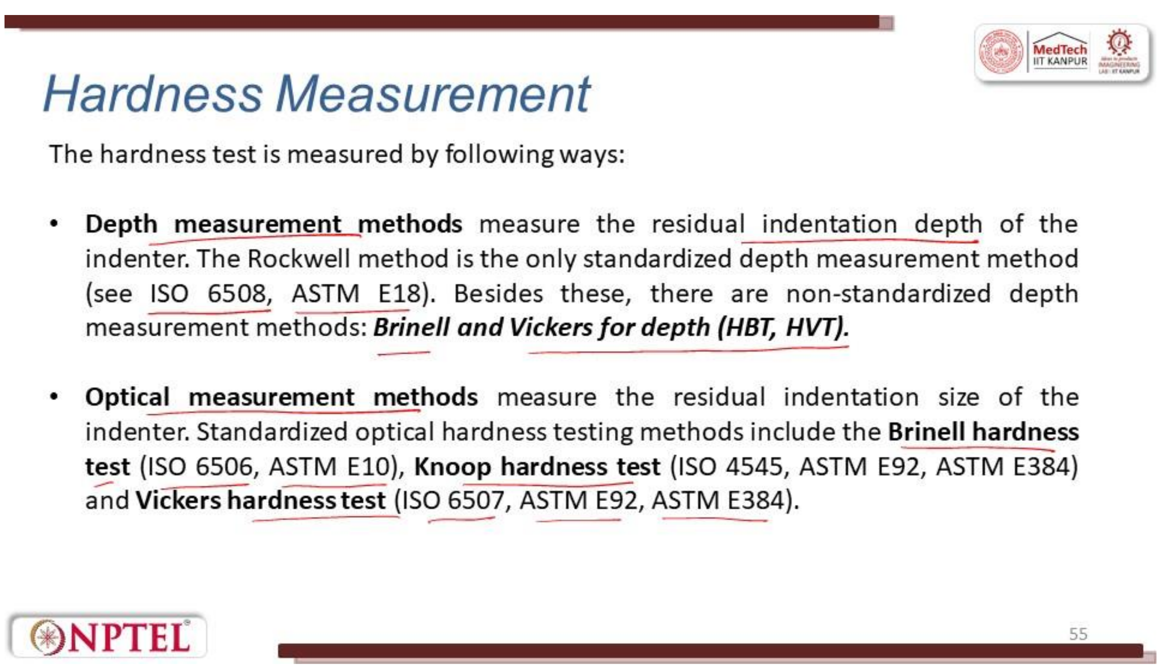


What is Objectives of Hardness Testing? Hardness testing is an essential aid in the differentiation of materials as well as for the analysis, development and improvement of materials and technologies within the framework of fundamental research that is material science, materials engineering, material diagnostics.

It is used to determine characteristics values that is hardness values which are critical for use of the material in industrial applications that is suitability of material for a technically relevant component their acceptance in control processes within the scope of the quality assurance that is again incoming and outgoing goods inspection as I mentioned.

So there could be differentiation of materials that is mix up of materials for the clarification of damage situations that is damage analysis, so I would put it here. Mix up of materials could be one area or for the damage analysis in the case of the damage situations.

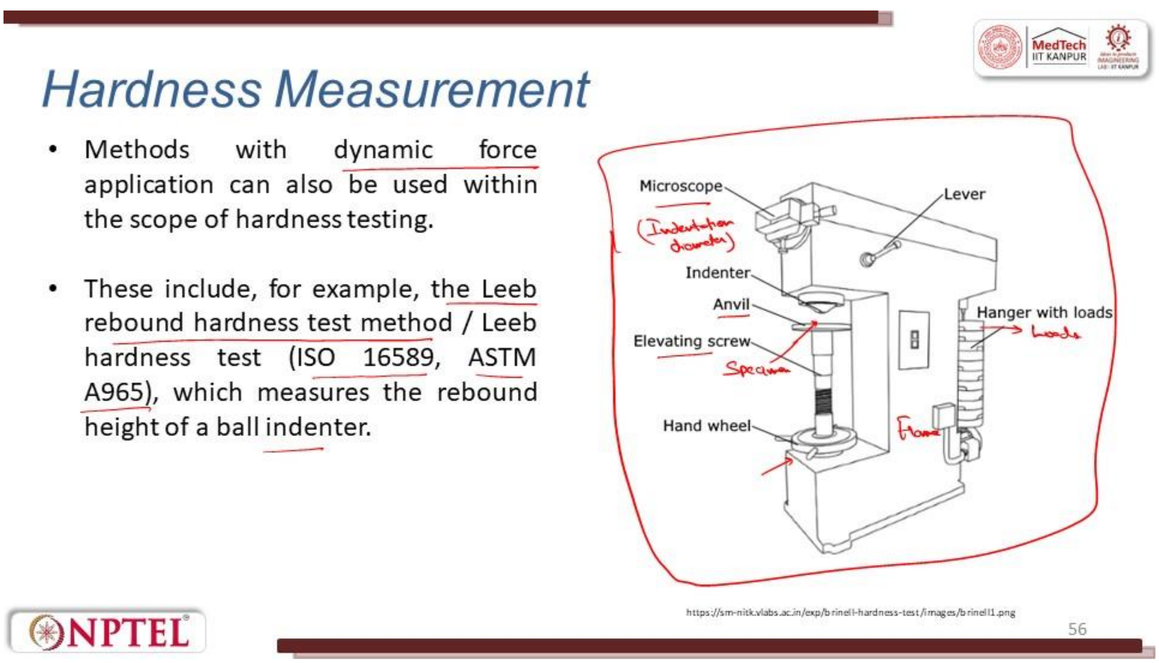
Methods with static force application are predominant for hardness test on metals. Measurements are either taken on the indentation depth or indentation size left behind by the indenter. For static methods in hardness testing, a differentiation is made between depth measurement methods and optical measurement methods. These are two methods, depth measurement methods. Method and optical measurement method.



Hardness Measurement. Hardness test is measured by following ways. Depth measurement method. Optical measurement method. Depth measurement methods measure the residual indentation depth of the indenter.

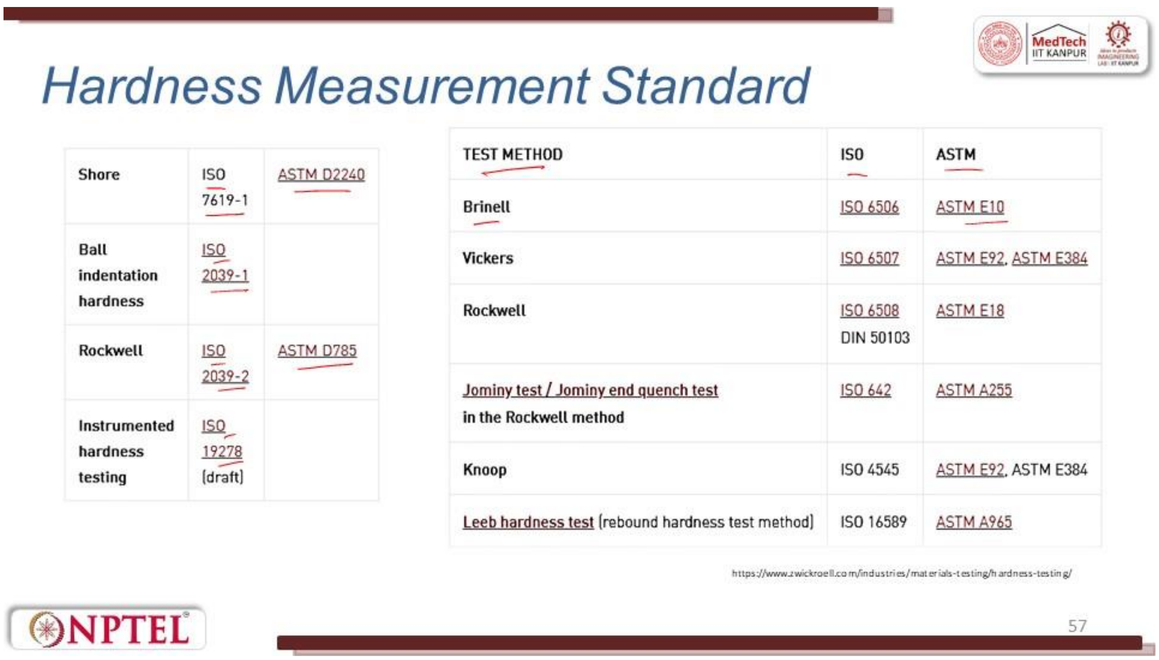
The Rockwell method is the only standardized depth measurement method which is built against the standards ISO 6508 and ASTM E18. Besides these, there are non-standardized depth measurement methods such as Brinell and Vickers for the depth measurement.

Optical measurement methods are there, optical measurement methods measure the residual indentation size of the indenter, standardized optical hardness testing methods includes brindle hardness test which is ISO 6506 and ASTM E10 Hoop hardness test which is ISO 4545 ASTM E92, ASTM E384. And weakest hardness test, ISO 6507, ASTM E92, ASTM E384.



Methods with dynamic force application can also be used within the scope of hardness test. These include, for example, the Leeb rebound hardness test method. Leeb hardness test is against ISO 16589 and ASTM A965, which measures the rebound height of a ball indenter. This is a typical hardness testing system or equipment where we have a complete system that has a frame here. We have hand wheel and we have a platen or we call it anvil where the specimen is kept. We put this specimen here.

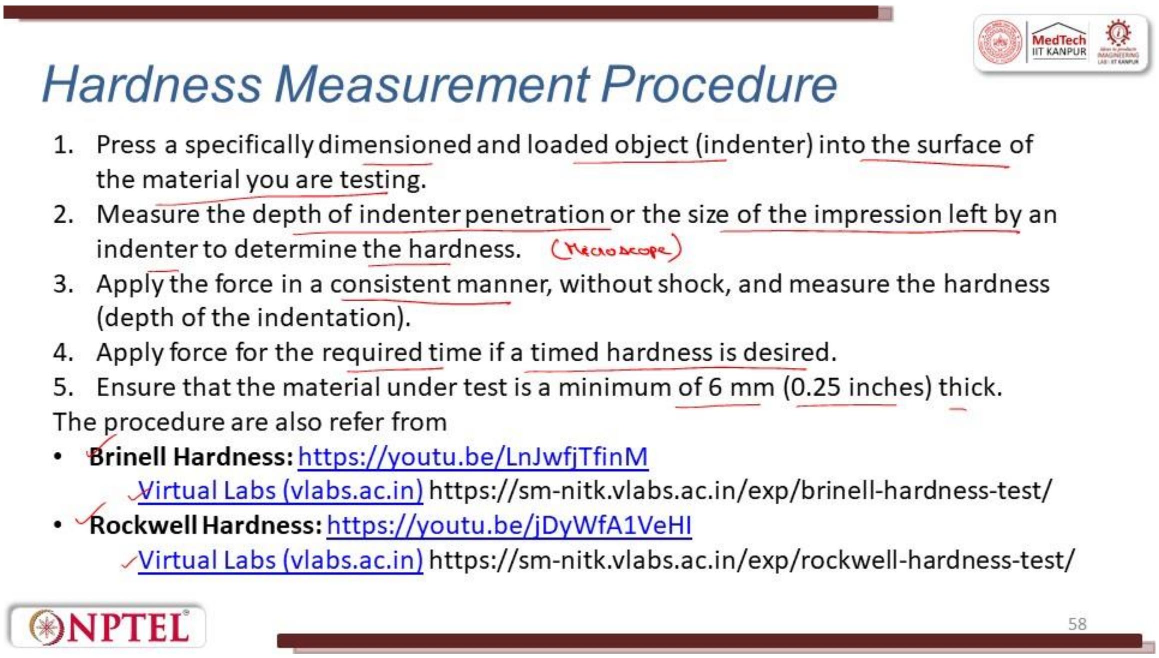
An indenter is there that indents inside the body. Then elevating screw to elevate the anvil up. Hand wheel is to rotate and to elevate using the elevating screw. We have a microscope that measures the indentation diameter that is measured by indentation. I will show you a video. Lever is to apply the load. There are hangers with loads. We can change the loads physically here. These are loads here.



Now, I will just show you the standards for Hardness Measurement. There are for instance, for shore, it is ISO 76191 ASTM D2240. For ball indentation hardness, it is ISO 20391 Rock Valley's ISO 20392 ASTM D785.

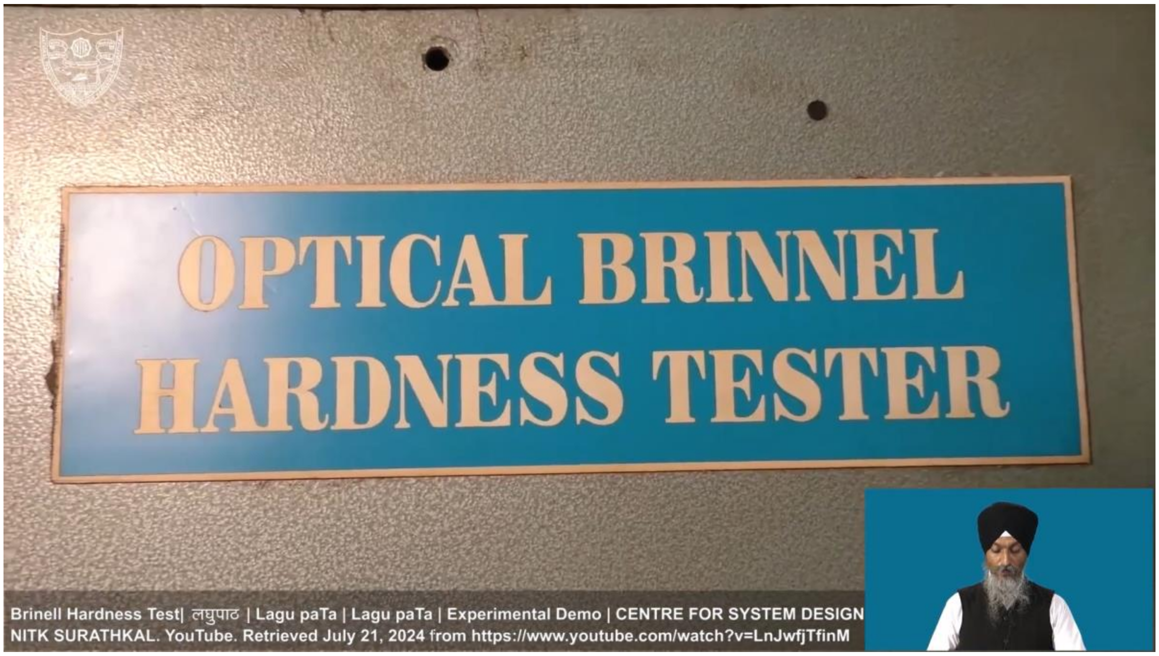
Instrumented hardness testing is against the standard ISO 19278. They are test methods, different test methods and ISO standards against them. For Brinell, it is ISO 6506 ASTM E10.

I have already mentioned these tests, these ISO standards in the previous slides. You can go through them.



Next is Hardness Measurement Procedure. First step is we press a specifically dimensioned and loaded object that is indenter into the surface of the material you are testing, then we measure the depth of the indenter penetration or size of the impression left by the indenter to determine the hardness, this is measured using microscope. Then we apply the force in consistent manner without shock and measure the hardness that is depth of intention.

Then we apply force for the required time if a timed hardness is desired. We ensure that the material under the test is minimum of 6 mm, that is 0.25 inches thick. I will go through the videos for Brinell hardness and Rockwool hardness and I'll also walk you through the virtual laboratory simulation for them.

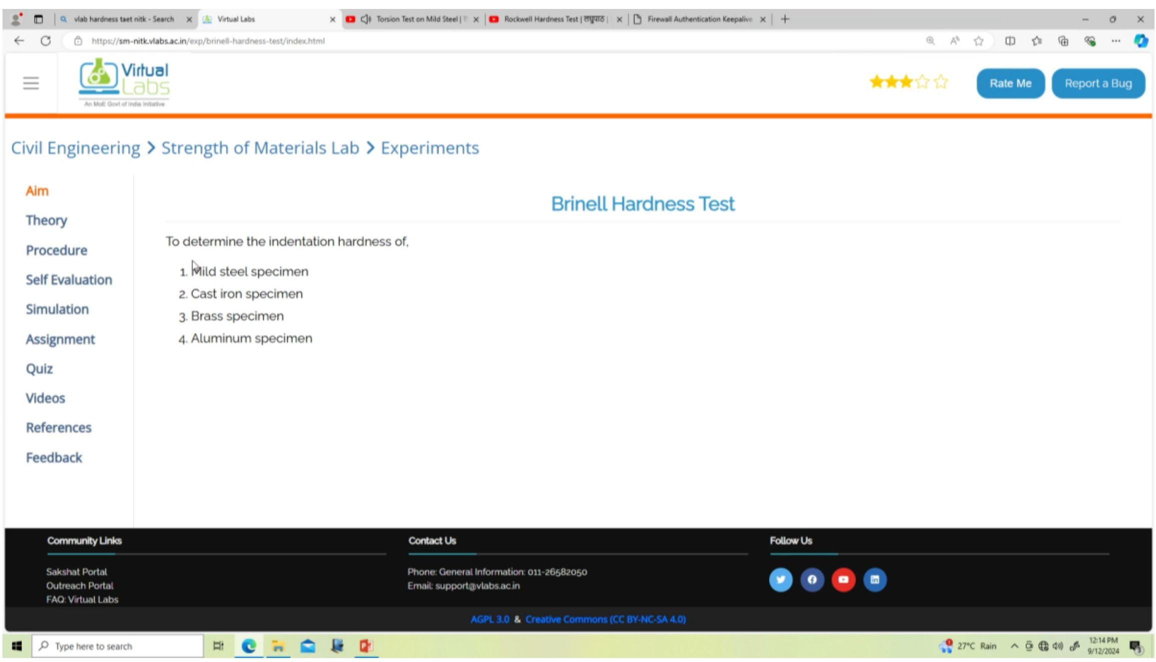


Let us watch the video for Brinell hardness that is also developed by Center of System Design NITK, Suratkal under the virtual laboratory project. This is optical Brinell hardness tester.

This is the experimental setup for Brinell hardness testing. The objective is to determine the indentation hardness of mild steel. We could use mild steel, cast iron, brass, any of the material that we wish to test. The indenter diameter is 10 mm. We select the load PE for the testing.

So, here P is 1000 kg. So, we turn the handwheel below, we put the specimen up and turn the handwheel below. So, motor is switched on so that the load is applied. The handwaver goes to the load position, the load is getting applied. For 10 to 15 seconds, the load is applied and then we pull the hand lever to the read position and through microscope we understand the reading or note the reading.

Then we unload it and try to put the readings in the observation and try to calculate the HBW that is brilliant hardness number. So, Brinell Hardness number is HBW that is HSO Hardness, B is for Brinell and W is for tungsten material. Tungsten is the material of the indenter. So, let me go through the virtual setup or the virtual laboratory experiment now.



This is the aim of the experiment in virtual laboratory for building hardness test that is to determine the indentation hardness of mild steel specimen, cast iron specimen, brass specimen, aluminium specimen.

Theory part is also given here where the machine which I showed you is here and we also watch the video that how does the indentation go and what are the steps here. The indenter diameter here is 10 millimeter when we talk about the Brinell hardness and HBW number that is hardness Brinell tungsten HBW number this is just a number that is dimensionless number. This is a relationship for this, it is $HBW = \frac{2P}{\pi D[D-\sqrt{D^2-d^2}]}$ where P is load in kg, HBW is brinell hardness number, which is in kg/mm^2. Capital D is diameter of the ball, small d is diameter of the indentation.

So, these relationships are there. So, you can all read about them. I will just go through the procedure. We will go step by step. Let me first go through the self-evaluation questions.

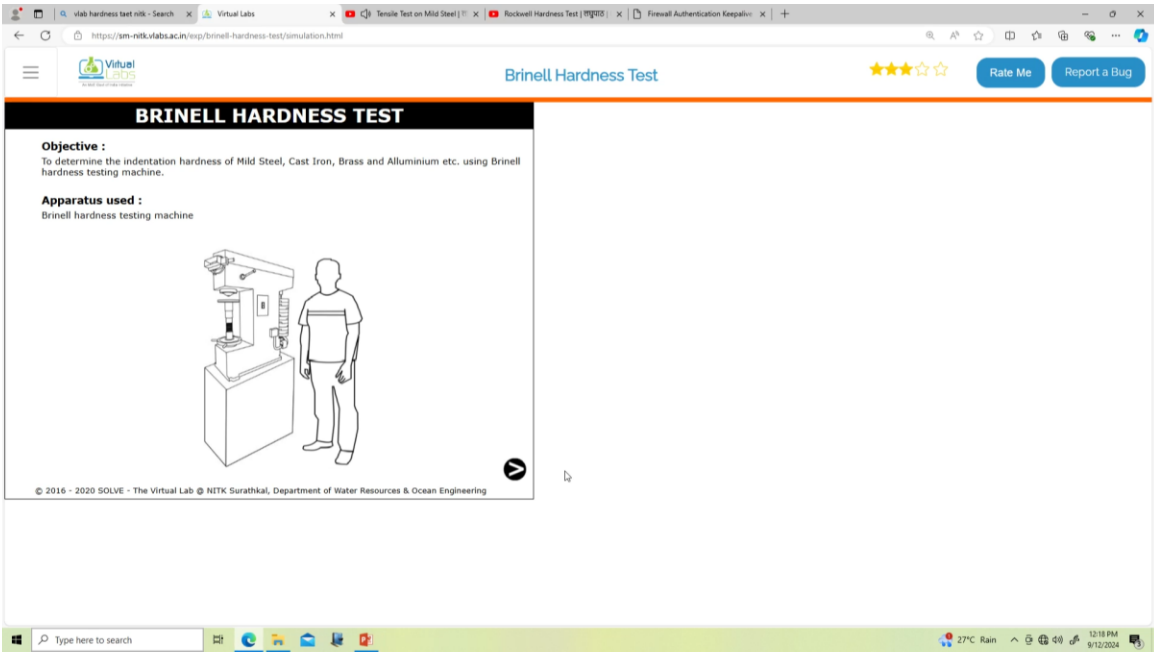
It is the pre-test evaluation. The first question here is the ability of the material to resist stress without failure is called. When we are talking about resisting stress without failure, it is strength. Second question, during hardness test, the indenter is usually a ball indenter, pyramid indenter, cone indenter, all of these. All of these shapes are there when we talk about the indenter shape.

In Brinell hardness test, the diameter of the ball used to test copper specimen is, there are different diameters for different specimens depending upon the known hardness or known hardness range of the material, the diameter is different. For copper, this diameter is 5 mm. Property of hardness of material is resistance to, as we have discussed already, it is resistance to indentation and we talk about indentation in the file inspection, scratching is also there, wear is also there. So, all of the above are the answers. So, property of hardness of material is resistance to scratching, wear, indentation, all of the three.

The ratio of test load to surface area of indentation in this test is this ratio is directly the Brinell hardness number. The value of distance between successive indentation is always lesser than distance of center of indentation from edge of specimen. This we have to determine whether true or false. The value of distance between successive indentation is always lesser than the distance of center of indentation from. No, this is not correct.

This is false. Diameter of impression is found by the microscopic observation that is there mounted in the testing machine itself. Select the correct statement from the following. A brittle material has no plastic zone. A ductile material has large plastic zone.

Both of them are correct. A rigid material has no plastic zone. All of these are correct. This was my pre-test assignment. I got 8 out of 8. So, this is correct.



Let us now go through the simulation. Here the objective is to determine the indentation hardness of mild steel, cast iron, brass, aluminium, etc. using Brinell Hardness testing machine. Apparatus uses Brinell hardness testing machine. The first step is diameter of the indenter is 10 mm.

We select load P based upon the type of the material selected. That is mild steel, cast iron, brass, aluminium, etc. So we select brass from here. Once brass is selected, then we have now gotten the P/D square ratios here, where P is load in kilograms, D is diameter of the indenter. So, P/D square = 30, that is load is 3000 kg.

P/D square = 10, that is load is 1000 kg. P/D square = 5, that is load is 500 kg. Each weight equivalent to 250 kg supporting hanging rod and base plate is 250 kg. So this is each weight here is corresponding to 250 kgs. So what we use the load value here is 1000 kg and selected material is dust.

Step 2. The specimen is placed on the supporting table, then the hand wheel below the table is turned in clockwise direction until the gap between the surface of the specimen and indenter is 5 mm. So I will just click here so that this is rotated and this there is a gap between the indenter and the specimen. It is not contacted. Next step, we switch on the machine and then load and unload positions are there of the lever.

I turn the lever to the load position and then for 10 to 15 seconds, this load is applied. I can stop at any point. It is time going on. So maybe just at around 30 seconds, I stop. So this is trial one.

I go forward to the step four when hand lever is pulled back to unload position and diameter of impression is measured through a microscope that is attached to the apparatus. I will just click on the microscope screw here and note the reading. The measured diameter of indentation is 3.48 mm. This was trial 1. For trial 1, the diameter of indentation is 10 mm.

Load is 1000. P/D square is 10. Diameter of indentation is 3.48 and 3.48. Average is 3.48. d by D, that is the diameter of indentation by the diameter of the ball, that is the indenter, is 0.348.

From this, I calculate the Brinell Hardness number, that is HBW. That is calculated using the formula which I just mentioned and the average diameter is calculated by $\frac{dIx + dIy}{2}$. So, we calculate the hardness number that is 101.9. This was trial 1. Then we go for trial 2 where again we rotate the wheel, bring it close to the indenter.

So that the distance between the indent and the specimen is 5 millimeters. Then we go to the next step, we switch on the machine, we load the machine by turning the lever, then after around 15 seconds, I stop, then go to the next step to measure the diameter is 3.46, this is diameter of the indentation on the brass work piece then I again, measure my hardness. It is 103.12. So, two trials were taken for the diameter of indenter 10 and the load of 1000 kg. These two hardness numbers, that is Brinell hardness numbers, are averaged out to 102.51. So, this was Brinell hardness test.

Now, let us watch a video for Rockwell Hardness Test as well. Rockwell Hardness Test is little different from Brinell. It is a direct calculation, direct number that comes. It is on two scales, C and B. Let us see that.

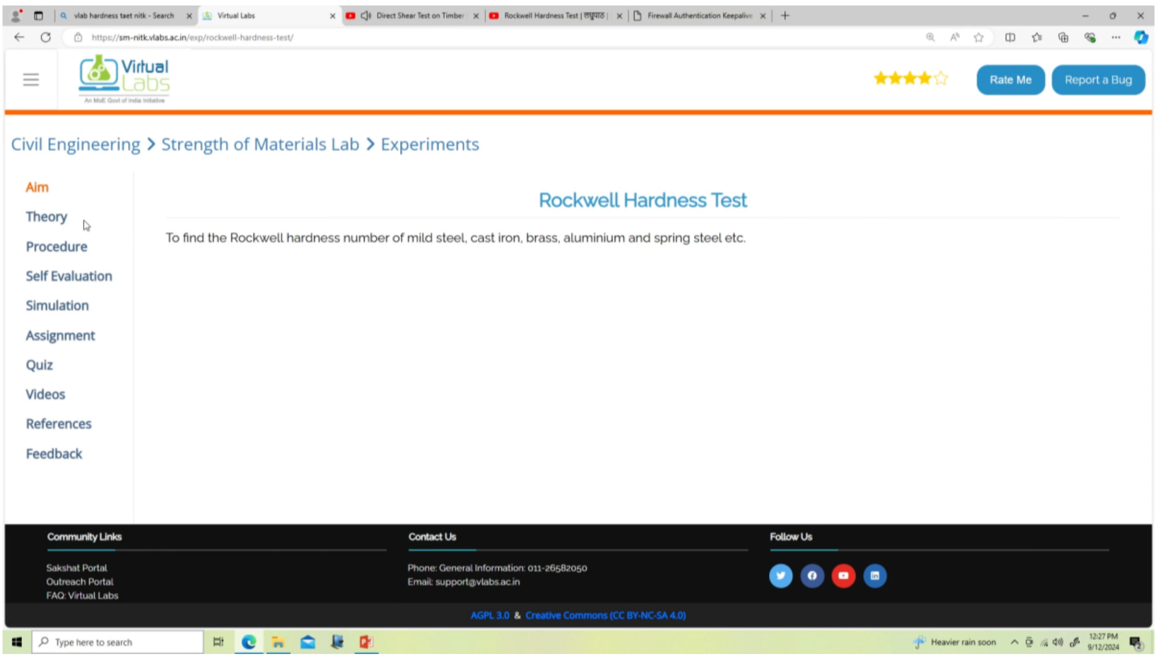
So, this is Rockwell Hardness Tester. So, this is experimental setup. Objective is to find the Rockwell hardness test or Rockwell hardness number for mild steel, cast iron, brass, aluminium, spring steel, etc. We select the specimen of our choice. We pick the brass as the specimen.

So, indenter is ball indenter. We fix the indenter into the position. We lock the indenter here. Once the specimen is selected, we place the specimen on the anvil and we rotate the wheel so that specimen is in contact with the indenter here. So, then this smaller dial gauge pointer should reach to 10 kg of the load.

So, based upon the material used, we select the major load. So, there are two loads here, minor and major. So, then we put the lever to the lower position. So, 10 to 15 seconds is load is there. Now, reading is noted down here.

So, here the reading is for C scale because brass is the specimen. So, here Rockwell Hardness number is 91. Then we unload the specimen. Then we take off the specimen. We can put the other specimen there and try to again take reading.

For different specimen, we can take readings and Rockwell Hardness number is a direct number. We do not have any calculations. It will just give you that number based upon the scale that you have selected. B and C scales are there for the harder and softer materials.



So, let me go through the virtual laboratory setup for this. This is the virtual setup for rockwell hardness test. The objective is to find the rockwell hardness number of mild steel, cast iron, brass, aluminium and spring steel etc., Just to cast a glance over the theory, this is the machine setup that is there. We have a dial indicator here. We have load device.

We have indenter, end wheel, elevating screw, hand wheel. Most of the systems are just like what was there in brinell hardness number. But only separate thing that we have is the loads here are there the part of the machine itself. There is a screw where you can select the load depending upon the material. And also it is a dial indicator that gives you the number directly.

Another difference is we apply load in two steps that is one is the initial load of 10 kg then the final load we can select for the specific material, initial load is always 10 kg so that the surface whatever the impurities if those are there, those are taken care of. Now hardness test can be conducted using different indented dimensions that is cone degree

120 ball for 1.58 millimeter, then cone for 120 degrees, initial load is all given, the major load is 50 kg, 100 kg, 150 kg for these sets of materials respectively.

The harder the material is, the more will be the load and the scale would be different, these are scales A, B, C, the dial gauge which I showed you had two scales B and C and the reading that we have gotten for the brass workpiece was in AB scale that is rockwell hardness number 91 that came in the video.

Now this is indentation how is the shape of indentation as all these things you can read, I'll just walk you through the self-evaluation questions and then we'll finally go to the simulation, the first question is what is the diameter of the rockwell barrel indenter? Rockwell bolinator diameter is 1 by 2 sooth.

That is 1/2 x 1/8th of inch. So, this is 1/16th of inch. Load applied for Rockwell C test is more than Rockwell B test. Yes, it is true. C is for the harder materials.

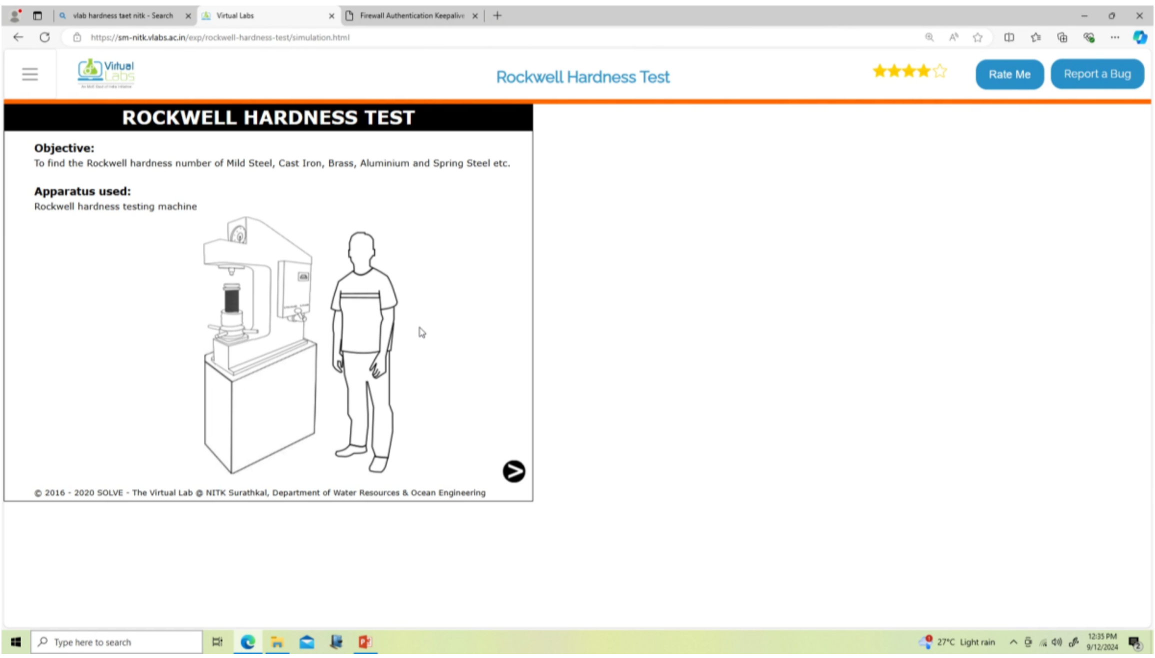
What is the unit of Rockwell hardness number? Rockwell hardness number has no unit. The answer should be dimensionless number. Match the following for Rockwell hardness test. So first point is minimum thickness of span.

Minimum thickness of span should be 10 times the permanent increase of the depth of indentation. So one matches with B. So one with B, I have two options, A and C here. So out of A and C, let me see another option. Second point here is distance between center of two adjacent impressions should be at least, this distance should be three times the diameter of the indentations. So this makes me select this option.

A-3, B-1, C-2. That is 2.5 times diameter of indentation is the distance between center of an impression and edge of specimen should be at least this value, 2 times of the diameter. Then for B, it is minimum thickness of span and C is 3 times the diameter of the indentation. That is distance between two adjacent impression, the minimum distance. Next question is, what is the value of minor load applied in the experiment?

This is 10 kg we have discussed. Why minor load is initially applied? Wonderful question. Minor load is initially applied so that the surface roughness or surface impurities are taken care of and the penetrator is firmly seat into the position for major load. Rockwell hardness number is obtained by Rockwell hardness formula, direct reading from the gauge.

Yes, it is direct reading from the gauge. There is no formula for it. Diamond indenter can be used for metals having hardness. Diamond indenter, because diamond is the hardest material, so any hardness value more than 20 HRC, diamond indenter can be used. In C scale of rockwool hardness testing, the shape of indenter used is in C scale because it is the hardest diamond cone indenter is used. So, we can submit the quiz here and we can go for the simulation part next.



So this is the simulation environment. Objective is to find the Rockwell hardness number of mild steel, cast iron, brass, aluminum, spring steel, etc. Apparatus used is the Rockwell hardness testing machine. Step one is to select the specimen.

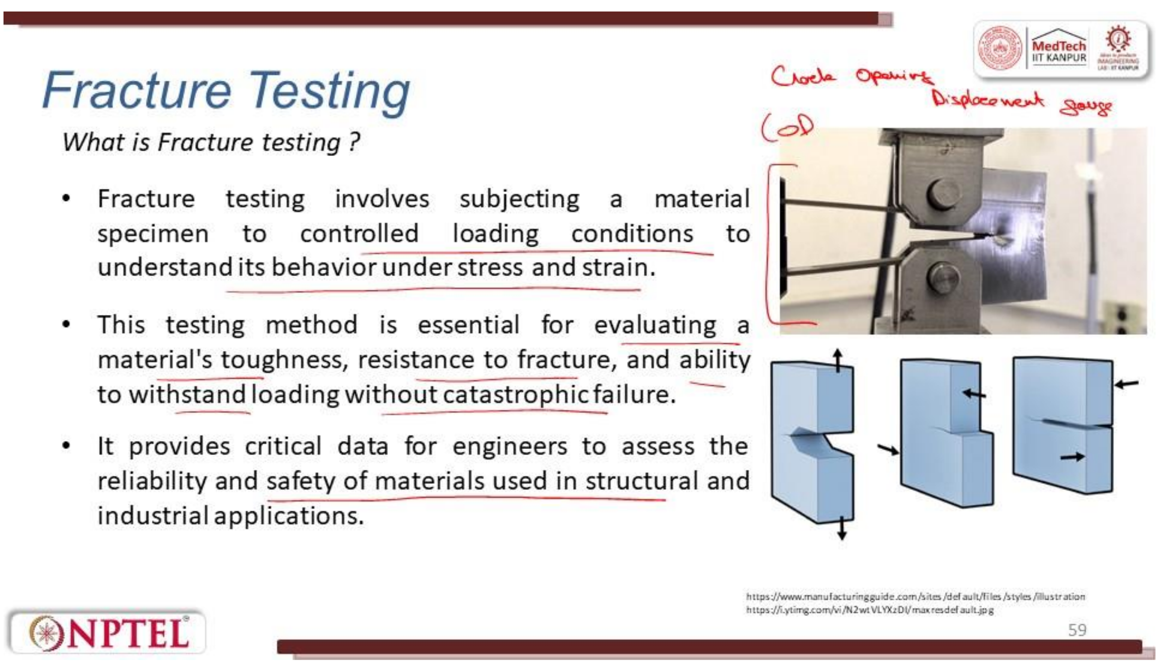
We will select brass as the specimen and type of indenter that we will use is ball indenter. The hand wheel is turned until the specimen is in contact with the indenter and the pointer of the smaller dial gauge reaches to the red dot. So, we are rotating the pointer so that the pointer reaches the red dot. It has reached the red dot and then we go to the next step. This is trial 1 going on.

And we set the load to 100 kg. Major load applies 100 kg. Then we switch on or we turn the lever to apply the load. So now load is being applied for around 15 seconds. We can again turn off the load by pressing the hand lever and it is showing the reading here.

That is the leader, the larger leader is showing the Rockwell hardness number that is 79. This was trial 1 where B scale is used, load is 100 kg and Rockwell hardness number is 79. Let us go for trial 2. In trial 2, again I will rotate the wheel so that here the minor load is set to the red point. So minor load of 10 kg is applied.

Then go to the next step and adjust the load. That is the major load 200 kg. Once it is adjusted to 100 kg, we turn the lever on to apply the load. After around 15 seconds, we turn off the lever and rocker hardness number would come. That has come as 80.

In the first trial, it was 79. Second trial is 80. So, average of these to be taken and the average is 79.50. This is directly, we have gotten Rockwell hardness number. So, this was a demonstration on the hardness test. Hardness is resistance to indentation, resistance to scratch, resistance to wear.

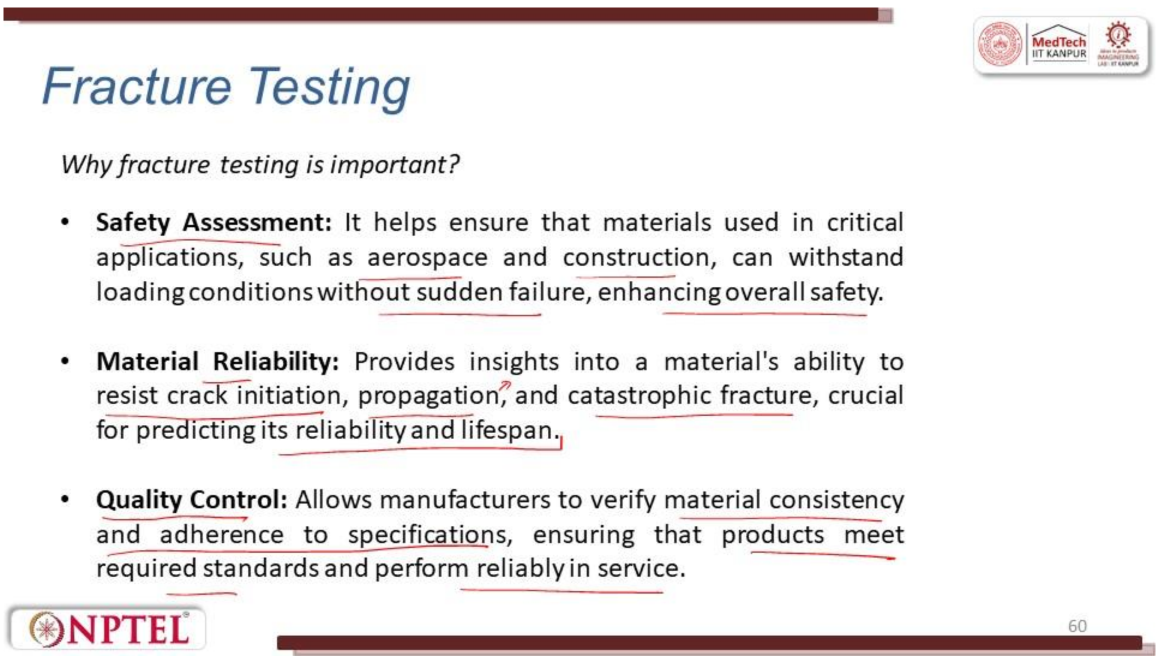


Now, I will take you to the Fracture test, a quick demonstration on that. I will just walk you through the small theory part and walk you through a video only. We do not have the simulation available for the fracture test. So, we only walk you through the video.

So what is Fracture test? Fracture testing involves subjecting a material specimen to controlled loading conditions to understand its behavior under stress and strain. So this is strength testing. Hardness is different, that is resistance to indentation. Strength is resistance to deformation.

So, fracture testing is for strength. This testing method is essential for evaluating a material's toughness, resistance to fracture, and ability to withstand loading without catastrophic failure. To provide critical data for engineers to assess the reliability and safety of materials using structural and industrial applications, fracture test is conducted. It is a specimen that is fractured. There are various ways to conduct this test.

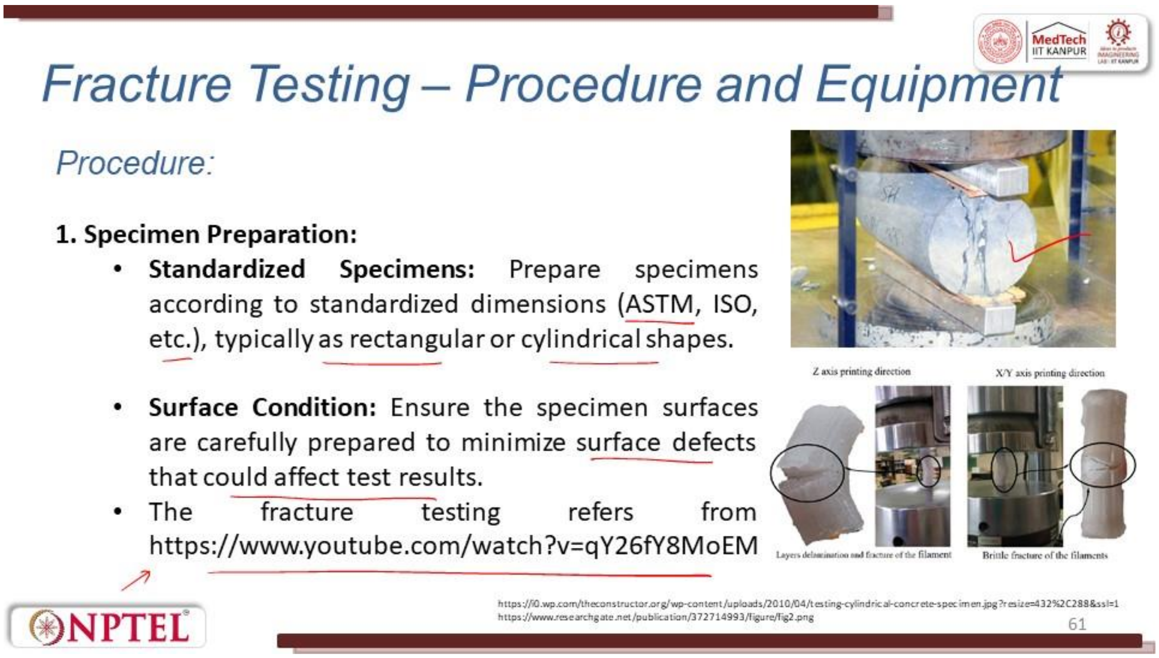
So there is an extensometer that is COD extensometer. This helps us to understand what is the extension that is going on, where COD is 'Crack Opening Displacement Gauge'.



Why is fracture testing important? First point is safety assessment. It helps to ensure that materials used in critical applications such as in aerospace, in construction, can withstand loading conditions without sudden failure, enhancing overall safety, material reliability,

It provides insights into materials ability to resist crack initiation or crack propagation and catastrophic fracture. Crucial for predicting its reliability and lifespan. That is generally the correct fracture is not there. But if it is propagated slowly or some catastrophic failure could happen. So this is tested using the fracture test.

Quality control. It allows manufacturers to verify material consistency and adherence to specifications. That is material strength or fracture strength is determined here, which ensures that the products meet required standards and perform reliably in service.



So procedure, we prepare the specimen according to the standard dimensions ASTM or ISO standards. Centers are there which are typically rectangular or cylindrical in shape, this is a cylindrical specimen that you can see in the previous slide we had the rectangular specimen.

For fracture testing surface condition is only to make sure that surface defects should not be there that affect the test results, I will show you this video.

Fracture Testing – Procedure and Equipment

2. Testing Apparatus Setup:

- **Fracture Testing Machine:** Utilize a specialized testing machine designed for fracture testing, such as a tensile testing machine for measuring fracture toughness or a Charpy impact tester for impact testing.
- **Specimen Mounting:** Securely mount the specimen in the testing apparatus to ensure it remains stable during testing.

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Testing apparatus include Fracture Testing Machine. Here we should realize a specialized testing machine designed for fracture testing such as a tensile testing machine we use for UTM and for Charpy Impact Test we use a specific testing machine. So there is a fracture testing machine that is utilized here. Specimen is securely mounted over the machine so that it remains stable during the testing.

Fracture Testing – Procedure and Equipment

3. Loading and Testing:

- **Application of Load:** Apply controlled loading conditions to the specimen, which may include tension, compression, bending, or impact, depending on the type of fracture test being conducted.
- **Data Acquisition:** Use sensors or transducers to measure load, displacement, and other relevant parameters during the test.
- **Monitoring Crack Propagation:** Record and monitor the progression of cracks within the specimen to analyze crack growth behavior.

Loading and Testing. Application of Load. We apply controlled loading conditions to the specimen, which may include tension, compression, bending, impact, depending on the type of fracture test being conducted. Date Acquisition. Sensors and transducers are used to measure the load, displacement, and other relevant parameters during the test. Monitoring crack propagation. We record and monitor the progression of cracks within the specimen to analyze crack growth behavior.

The crack growth behavior means in the beginning, the crack would be very small. The crack would keep growing. And when the crack completely happens, the load will just be released in a way. So that propagation and the flow of the crack growth is studied here.

Fracture Testing – Procedure and Equipment

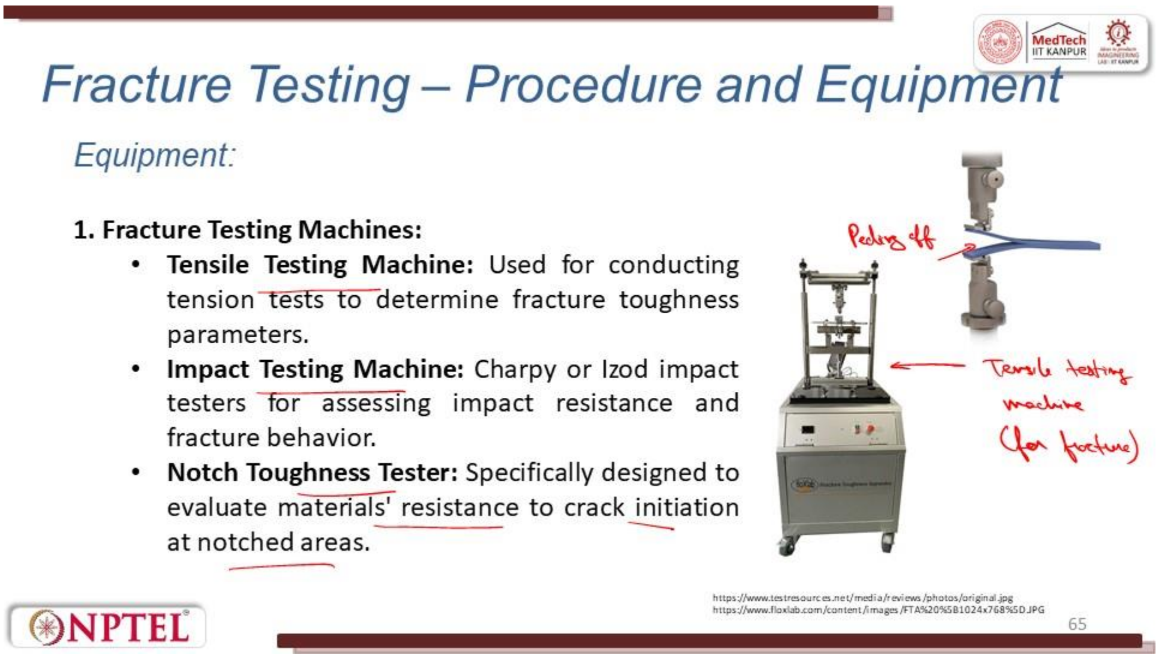
4. Analysis of Results:

- **Fracture Toughness:** Calculate fracture toughness parameters, such as critical stress intensity factor (K_{IC}) which indicates a material's resistance to crack propagation.
- **Energy Absorption:** Evaluate the energy absorbed during fracture to understand the material's ability to dissipate energy under loading.
- **Fracture Surface Examination:** Inspect and analyze the fracture surface of the specimen using microscopy or other techniques to determine the fracture mechanism and identify any contributing factors.

Brittle
Ductile
Slow
Rapid

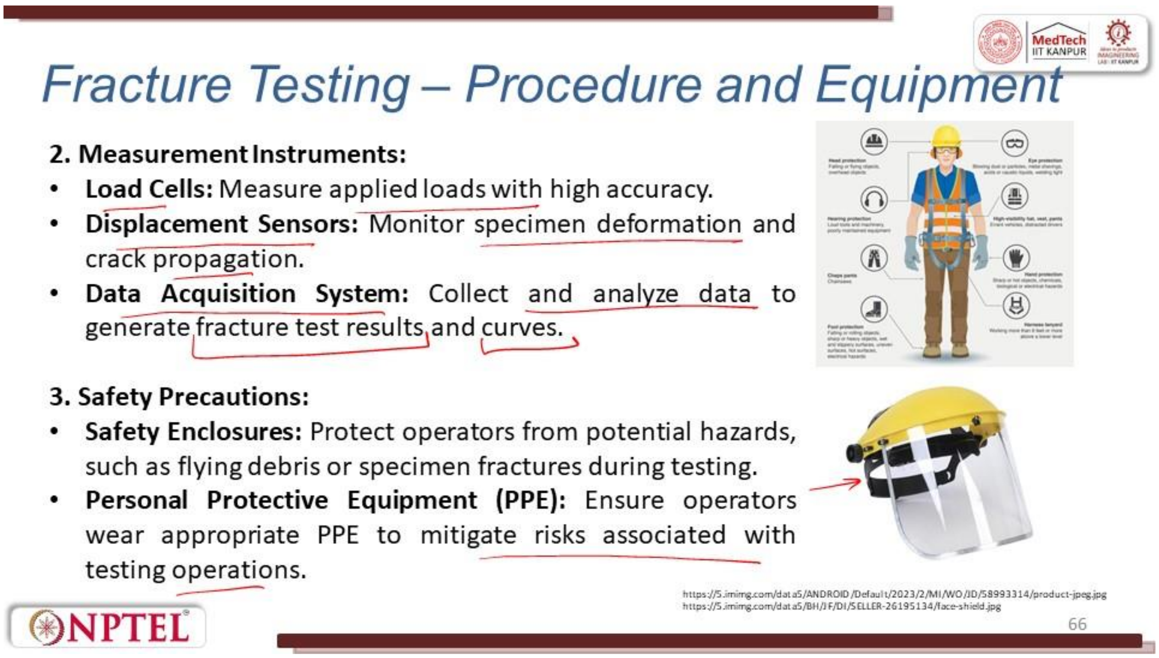
Analysis of Results. First thing that we try to understand from the fracture testing is fracture toughness. We calculate the Fracture Toughness parameters such as critical stress intensity factor, that is KIC, which indicates a material resistance to crack propagation. Energy Absorption. We evaluate the energy absorbed during fracture to understand the material's ability to dissipate energy under loading. Fracture surface examination.

We inspect and analyze the fracture surface of the specimen using microscopy or other techniques to determine fracture mechanism and identify any contributing factors. So that is fracture mechanism could help us understand whether it was brittle, whether it was ductile, whether it was slow or whether it was rapid. These properties are taken from the fracture surface.



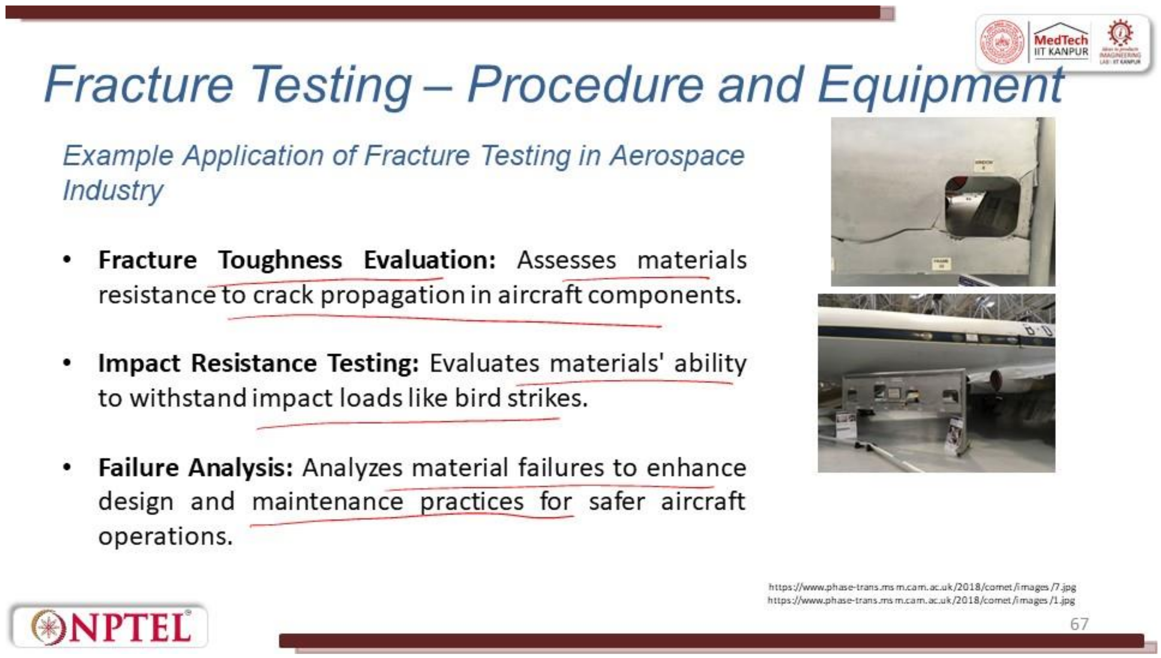
Equipment includes the testing machine such as tensile testing machine used for conducting tension test to determine the fracture toughness parameters. We have impact testing machine that is Charpy Izod impact testers for assessing impact resistance and fracture behavior.

So, this is peeling off. So, this is our tensile testing machine for fracture, then notch toughness tester is there that is specifically designed to evaluate material resistance to crack initiation at the notched areas. Different setups are there.



Measurement instruments include load cell, displacement sensors, data acquisition system. Load cells measure the applied load with high accuracy. Displacement sensors monitor specimen deformation and crack propagation.

Data acquisition system collects and analyzes data to generate fracture test results and curves. Safety precautions, safety enclosures, that is, to protect the operators from potential hazards, safety enclosures are there, which include the PPE, which ensures operators wear the appropriate equipment, that is the protective equipment, so as to mitigate risk associated with testing apparatus.



Procedure, fracture toughness evaluation that assesses material resistance to crack propagation in aircraft components, then impact resistance testing that evaluates material's ability to withstand impact loads like bird strikes or so, then failure analysis that analyzes the material failures to enhance design and maintenance practices for safer aircraft operations. So I will walk you through the video, the pass to which is given in this slide.

Let us go through this video and try to understand how structure testing is conducted. This video is from Zurich Oil TV, who are the manufacturers of the mechanical testing machines. In this video, you can see a fracture testness test on ASTM 399 material is used using the HA 250 machine. HA 250 means 250 kN of load is applied in this machine with 100 mm of the stroke. So, it is a hydraulic setup machine in which different grips are there.

It is a COD extensometer that is there and compact tensile specimen is there. So this is the interface that is the user interface of the machine where we can input the dimensions of the specimen. Specimen dimensions are measured and put it here. It is 25.57 of thickness and width is put 63.75. Then we mount the specimen into the CT grips here.

We put the pins here and pins are locked. Now, the COD sensor meter on the blades is attached here to the CT specimen so that we measure what is the extension value. And here testing frequency is set first. We put the force value that is 1 kilonewton. Now, fracture testing is started here.

You can see the way the loading is happening. Pre-cracking, this is how the machine behaves. And it is also plotting the live fracture here. So crack opening is also there, running the fracture toughness. So this is the fracture crack has happened now.

Now you can see suddenly fall of the load is there. This is how the fracture test is conducted. We are measuring the crack length directly from the specimen. And this surface of the specimen also tells you about the properties or the behavior, what the specimen is. We put the values of the different dimensions here, that is what is ligament or so.

Then we generate the report that this is the results taken from the fracture toughness, so this is what the modern machines helps us to understand the toughness that is the fracture toughness in different forms. So there are certain features always for machines which are different by the different manufacturers, here they have also given that a simple integration of accessories high temperature furnace is also there in this setup.

So, there are multiple ways fracture testing is conducted using the sharp impact test systems, using the tensile systems or using the systems where the fracture at the notch is to be tested. That is the notch toughness testers are there. So, this was about the hardness test and fracture test in this lecture.

We will meet in the next week where we will talk about the cam, the belts, the chains, the gears and we will continue the lecture series on Basics of Mechanical Engineering 1.

Thank you.